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# Effective policies for renewable energy—the example of China's wind power—lessons for China's photovoltaic power

Qiang Wang [a,b,c,*]

[a] Qingdao Institute of Bioenergy and Bioprocess Technology, Chinese Academy of Sciences, Qingdao 266101, China
[b] Guangzhou Institute of Geochemistry, Chinese Academy of Science, Guangzhou 510640, China
[c] Graduate University of Chinese Academy of Sciences, Beijing 100049, China

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ABSTRACT

China, one of the global biggest emitter of $CO_2$, needs promotion renewable energy to reduce air pollution from its surging fossil fuel use, and to increase its energy supply security. Renewable energy in its infancy needs policy support and market cultivation. Wind power installed capacity has boomed in recent year in China, as a series of effective support policies were adopted. In this paper, I review the main renewable energy policies regarding to China's wind power, including the *Wind Power Concession Program*, *Renewable Energy Law*, and a couple of additional laws and regulations. Such policies have effectively reduced the cost of wind power installed capacity, stimulated the localization of wind power manufacture, and driven the company investment in wind power. China is success in wind power installed capacity, however, success in wind-generated electricity has yet achieved, mainly due to the backward grid system and lack of quota system. The paper ends with the recommended best practice of the China's wind power installed capacity might be transferable to China's photovoltaic power generation.



**Contents**



* Correspondence address: Qingdao Institute of Bioenergy and Bioprocess Technology, Chinese Academy of Sciences, Qingdao 266101, China. Tel.: +86 20 85290957; fax: +86 20 85290125.
*E-mail address:* tswangqiang@yahoo.com.cn.

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## 1. Introduction

China is now the world's second-largest energy producer and consumer [1], and is projected to overtake the US to become the world's largest energy consumer soon after 2010 [2]. Currently, nearly 70% of China's primary energy is derived from its vast coal reserves [3]—the third largest in the world. But coal is an aggressive pollutant, and one of the main sources of greenhouse gases, thus wide use coal has added stress to a country that is one of the world's biggest emitter of $CO_2$ [4]. Managing Chinese gargantuan energy demand and greenhouse gas emissions are gigantic challenges for China. Renewable energy would be an ideal solution, as renewable energy neither deplete natural resources, nor cause $CO_2$ or other gaseous emission into air or generates liquid or solid waste products.

However, a variety of barriers from market or non-market conditions prevent investment renewable energy from occurring. Hence, renewable energy needs policy support and market cultivation in its infancy. The rapid growth of wind power installed capacity is a good example. Before a series of effective energy policies were enacted, China's wind power developed slowly; since these policies were enacted, China's wind power has experienced a rapid growth. In 2007, cumulative wind installations in China exceeded 5 GW (gigawatts) [5], the goal originally set for 2010 by *The Medium and Long-term Renewable Energy Development Plan* [6]. So, in 2008, policymakers had to double their wind power prediction (10 GW) for 2010 [7]. Still the total of wind power installed capacity reached 12.15 GW by 2008 [8]. China's wind power installed capacity is expected to 100 GW, ranking the country's third-largest power resource after coal and hydroelectric power by 2020 [9].

The success factors of China's wind power case might be transferable to China photovoltaic power generation. China is rich in solar energy. More than two-third of the country receives an annual radiation of more than 5000 MJ/m$^2$ and more than 2000 h of sunshine [10]. Moreover, China is the leading producer of solar cell. The total output of China's solar cell in 2007 was 1088 MW (megawatt), ranking it first in the world. However, by the end of 2007, the total installed capacity of photovoltaic power generation was only 105 MW [11].

This paper is structured as follows; I shall first give an outline of China facing challenge from energy demand and carbon emission. Next I shall review the renewable energy policies regarding to the booming wind power installed capacity, and main barriers to a further development of wind power in China. And finally I study the described success factor of the wind power might be transferable to the photovoltaic power generation.

## 2. Twin challenges China facing

### 2.1. Global warming

As a developing country, China's per capita $CO_2$ emission is lower than the world's average [2] (see Fig. 1), but the large population and high speed of economic development have been primary drivers of the recent acceleration in global carbon emissions [12]. China's economic growth is projected to continue at higher than 7% per year; at this rate, GDP would quadruple in 20 years [13]. In a hypothetical scenario in which carbon intensity keeps pace with a GDP growth rate of 7%, by 2030, China would be emitting as much as the world as a whole is today (8 GtC/year) [14].

However, China will be one of the worst impacted regions in the world if climate changes as predicted [14–16]. For example, global warming could make China's agricultural output reduced by 5–10% by 2030 [16], thus adding stress to a country that has 20% of the world's population and only 7% of the arable land. In addition, three main industrial centers of China are on lowland areas: the Gulf of Bohai region with the Beijing-Tianjin axis, the Yangtze River delta radiating inland from Shanghai, and the Pearl River delta encompassing Hong Kong and Guangzhou. A sea level rise of a meter would inundate 92,000 km$^2$ of land in these three regions [14,16].

### 2.2. Increasingly energy demand

China is an emerging economy with the averaging 9.8% annual increase in gross domestic product (GDP) since introduction reform and opening-door policy in 1978. The thrust behind China's terrific economic growth is provided by large injections of energy (see Fig. 2), derived primarily from coal (nearly 70% of the total primary energy consumption) [3].

China's primary energy demand is projected to more than double from 2005 to 2030 (see Fig. 3). With four times as many people as the United States, China will overtake the US to become the world's largest energy consumer soon after 2010 [2]. However, the reserves of coal, oil and natural gas resources of China rank 3rd, 13th and 17th in the world, respectively. Moreover, per capita coal, oil and natural gas reserves in China only reach 79%, 6.5% and 6.1% of the world average level, respectively [17]. In the first half of 2007, China became a net coal importer. China's net import is projected to reach 3% of its demand and 7% of global coal trade in 2030 [2]. As far as oil, China surpassed Japan to become the second-largest oil consumer in 2003, and become the second-largest oil importer in 2005. Currently, nearly half of China's oil consumption needs import [18]. It is projected that China's net oil imports jump from 3.5 mb/d in 2006 to 13.1 mb/d in 2030, according to the Reference Scenario of International Energy Agency (IEA) [2].

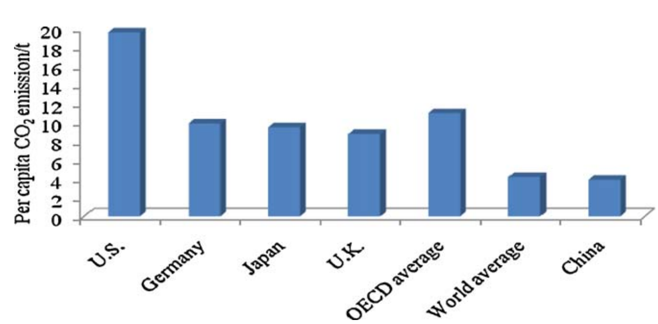



**Fig. 1.** Comparison of per capita emission of $CO_2$ in the world [2].

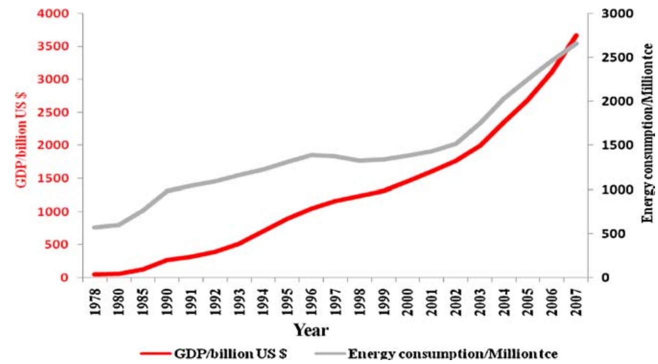



**Fig. 2.** The correlation between GDP growth and energy consumption [3].

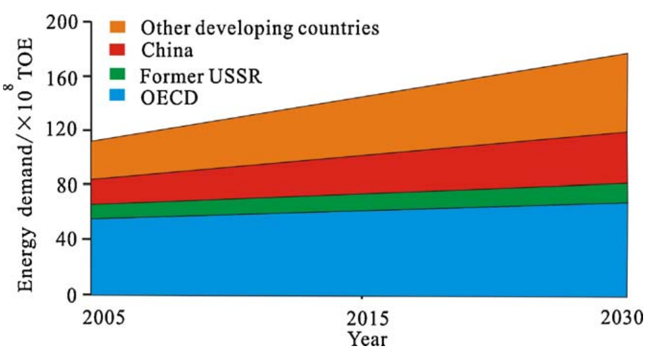



**Fig. 3.** Prospect of energy demand in different regions [2].

The great pressure from curbing carbon emission and the increasingly need of energy have forced China turn to renewable energy, as renewable energy does not deplete natural resources, does not cause $CO_2$ or other gaseous emission into air or generates liquid or solid waste products. However, a variety of barriers or conditions prevent investment renewable energy from occurring. Often the result of barriers is to put renewable energy at an economic, regulatory, or institutional disadvantage relative to other forms of energy supply. Many of these barriers could be considered "market distortions" that unfairly discriminate against renewable energy, such as poor market acceptance, imperfect capital markets, technology prejudice; while others have the effect of increasing the costs of renewable energy relative to the alternatives, such as subsidies for conventional forms of energy, high initial capital costs, high transactions costs [19–23]. So, renewable energy in its infancy needs policy support and market cultivation to overcome such barriers. The rapid growth of China's wind power installed capacity is a good example.

## 3. Assessing the success of policies in China's wind power

### 3.1. The resource of China's wind power

Throughout China's vast land mass and long coastline, there is a rich resource of wind energy with great development potential (see Fig. 4 and Table 1). As shown in Table 1, the wind energy can be utilized in more than 75% of China, the wind energy density is more than 50 W/m$^2$, and the accumulative total hours when wind speed $\geq$3 m/s is more than 2000 h. According to the results of the last national investigation, the theoretical potential of wind power in China amount to 700–1200 GW [24].

### 3.2. Policies regarding to the wind power

China's grid-connected wind power started to develop in the 1980s. In 1986, the first pilot wind farm was established in Rongcheng City, East China's Shandong Province [26,27]. And its development is divided into three stages: 1986–1993 initial pilot stage, 1994–2003 wind power generation industry development

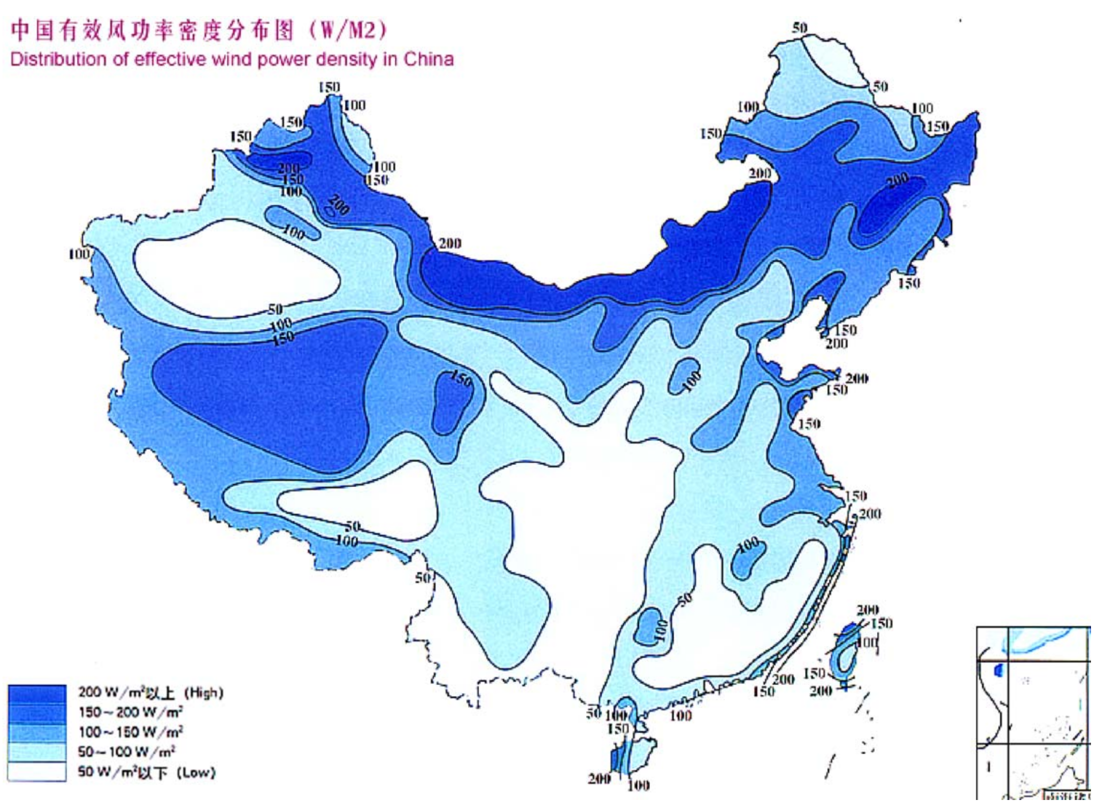



**Fig. 4.** Distribution of effective wind power density [25].

**Table 1**
The wind energy distributing zone and the share percent of country area [25].

| Wind energy index | Best abundant | Better abundant | Available | Deficient |
|---|---|---|---|---|
| Wind energy density (W/m$^2$) | >200 | 200–150 | <150–50 | <50 |
| Average wind speeds (m/s) | 6.91 | 6.91–6.28 | 6.28–4.36 | <4.36 |
| Accumulative total hours when wind speed ≥3 m/s | >5000 | 5000–4000 | 4000–2000 | <2000 |
| Accumulative total hours when wind speed ≥6 m/s | >2200 | 2200–1500 | <1500–350 | <350 |
| The share percent of country area (%) | 8 | 18 | 50 | 24 |

**Table 2**
Government wind power model projects in China during the second phase.

| Time | Project | Brief introduction |
|---|---|---|
| 1993 | National Wind Power Work Meeting | The first national meeting of wind power, showing that wind power has been attracted the government's attention |
| 1996 | Fair Wind Project | During the 10th 5-year Plan (2000–2005), 60–80% or more wind machinery produced by China |
| 1997 | Dual Pluses Project | Invest 90 million Yuan (US$ 13 million) to accelerate wind energy power generation and the wind energy machinery state-manufacturing process |
| 2000 | State Debt Wind Energy Power Generation | Construct 80 MW China-made wind energy power generation group model wind power field |
| 2000 | 10th 5-year Plan (2000–2005) | Up to 2005, the installed capacity for wind power generation reached 1.5 GW |
| 2000 | Renewable Energy Industrial Development Plan | Up to 2015, the installed capacity for wind power generation reaches 7 GW |
| 2002 | Acceleration Plan for Bright Project | Provide a capital of 180 million Yuan (US$ 27 million) for solar energy and wind energy projects |

stage, and stage for scaling-up wind power development from 2003 [24,28]. China's wind power had been experienced a slow development before entering into the third phase.

In the initial stages (1986–1993), the main activity was to build small-scale demonstration wind farms by utilizing grants from foreign donor countries and loans. The price paid for electricity exported to the grid was so low that only meet the requirement of wind farm maintenance. For example, the price of the Dabancheng wind farm in Xin Jiang Province was less than 0.3 Yuan (US Cent 4.4)/kWh, almost the same as for fossil fuel power [28].

During the second stage (1994–2003), a series of "Projects" or "Plans" was released to advance China's wind power, such as "*National Wind Power Work Meeting*", "*Fair Wind Project*", "*Dual Pluses Project*", "*Renewable Energy Industrial Development Plan*" (see Table 2). However, the wind power industry had developed slowly during these two periods due to its high cost and vague policy support [5,24] (see Fig. 5).

The third stage (since 2003) was characterized by *Wind Farm Concession Program* [5,24,28]. I cover the most important of energy policies in regarding to wind power in this stage.

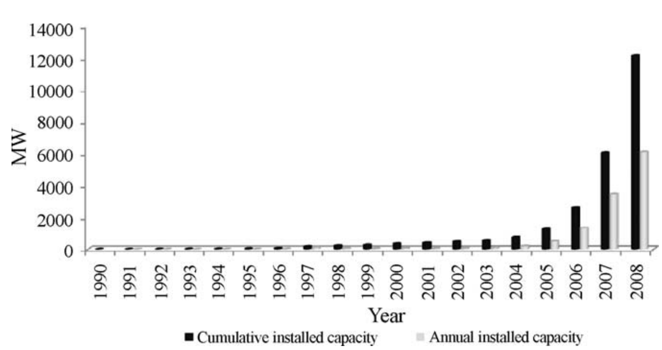



**Fig. 5.** The accumulative total of wind energy generating system in the past 14 years [5,8,24].

*3.2.1. Wind Power Concession Program (implementation in 2003)*

Although China's government has, for many years, encouraged the use of wind power, favorable conditions for wide-scale development have yet to develop. Then, Chinese National Development and Reform Commission (NDRC) initiated a new policy named "*Wind Farm Concession Program*" in 2003. Under the new policy, the investors and developers of wind power projects (more than 50 MW) are selected through bidding, with the aim to expand the rate of development and improve the manufacturing capacity of domestically made parts on the one hand, and to lower power generation costs and reduce electricity prices on the other hand. The main principles of the wind concession are as follows [24,28]:

- The wind farm projects of relatively large scale (installed capacity of or above 50 MW) are selected for concession bidding. Meanwhile, wind power projects with an installed capacity of or above 50 MW are approved only by the concession bidding.
- Investors are selected through public tendering by the government. At first, the bidder who offers the lowest price wins the bid. In 2005, the criteria were revised so that the electricity price was given 40% of the total weight in deciding the winning bids. This was further reduced to 25% in 2006, and then in 2007, the winning criterion was set as the bid closest to the average bidding price, excluding the highest and lowest bids. Local content of wind farm is another important criterion. In practice, the bidder who offers the lowest price and highest local content usually wins the bid.
- The provincial grid company must sign a power purchase agreement with the bid winners and purchase all the electricity generated by the wind projects.
- The grid company is responsible for investment in the concession of transmission lines and the connection between wind farms and the nearest network. The local government is responsible for construction of road access to the wind farms as well as coordination of some preparation work.

- The difference between the wind power price and that of conventional power must be shared across the provincial grid users. From 2006, the price difference is shared across the national grid.
- The wind concession lasts for 25 years and the bid price is guaranteed as a feed-in-tariff for the first 30,000 full load hours achieved. Depending on the site's wind resource, this could cover about 10–15 years. After 30,000 full load hours, the project owner will receive the average local feed-in-tariff on the power market at that time.

Some of these principles form part of the *Renewable Energy Law*.

*3.2.2. Notices the requirements of local content in construction wind power (implement in July 2005)*

In 4 July 2005, the NDRC issued "*Notices the Requirements of Local Content in Construction Wind Power*", which clearly stated that the wind concession projects have a local content requirement that has been increased to 70% from an initial 50% requirement when the concession program began in 2003. The notice provides a valuable opportunity for the development of domestic wind power manufacturer.

*3.2.3. Renewable Energy Law (implementation in January 2006)*

The landmark *Renewable Energy Law* was enacted in February 2005, and put into effect on 1 January 2006. This law is designed to "promote the development and utilization of renewable energy, improve the energy structure, diversify energy supplies, safeguard energy security, protect the environment, and realize the sustainable development of the economy and society" (Article 1) [29]. The law gave energy policy priority to the development and utilization of renewable energy [28]. Moreover, the crucial role of the landmark law makes China's renewable energy policy gain an overarching framework. The substance of the legal framework has been fleshed out in contemporaneous and follow-on regulations. Several governmental commissions and ministries have been involved in drafting the detailed regulations for the Law's implementation; more than ten regulations have been issued with a couple of additional ones still contemplated [30].

*3.2.4. Provisional Administrative Measure on Pricing and Cost Sharing for Renewable Energy Power Generation (implemented in January 2006)*

Three days later of the *Renewable Energy Law* was put into effective, the NDRC issued "*Provisional Administrative Measure on Pricing and Cost Sharing for Renewable Energy Power Generation*". The regulation stipulated that the wind power price should follow the government determined price. This price should be approved by the relevant department of the State Council based on the price of the tender. In addition, the regulations stated that the increment cost of renewable energy power generation over the standard wholesale price for desulphurization coal-fired generating units shall be shared among the sales volume of electricity in power grids at the provincial and above level. The incremental cost for purchasing renewable energy power generation by power grid companies will be settled via tariff surcharge levied on electricity end-users nationwide. Since 30 June 2006, an additional 0.001 Yuan (US Cent 0.015)/kWh has been charged to electricity consumers in order to compensate for the additional cost of renewable electricity. Since 30 June 2008, the tariff surcharge has increased to 0.002 Yuan (US Cent 0.03)/kWh.

*3.2.5. Tentative Management Method for Renewable Energy Development Special Fund (implement in June 2006)*

In June 2006, Ministry of Finance issued *Tentative Management Method for Renewable Energy Development Special Fund*, offering additional measures to enhance support for renewable energy development. The method provides for the special fund's assistance priorities, application for assistance, their screening and approval, financial management, tests and control, etc. Specifically, the method has allowed the central government to provide financial assistance for the development of wind power, solar and other renewable energy sources for power generation.

*3.2.6. Medium and Long-term Renewable Energy Development Plan (implement in August 2007)*

In August 2007, the Chinese government released *the Medium and long-term Renewable Energy Development Plan*. It states the shares of renewable energy in the total primary energy consumption will increase from 7.5% in 2005 to 10% by 2010 to 15% by 2015. As far as wind power, wind power installed capacity will be reached to 5 GW by 2010, and 30 GW by 2020, respectively [6].

*3.2.7. Management Methods for Power Grid Enterprises' Purchasing of Renewable Energy Electricity (implemented in September 2007)*

In July 2007, the Stated Electricity Regulatory Commission issued the "*Management Methods for Power Grid Enterprises' Purchasing of Renewable Energy Electricity*". Earlier, power grid enterprises were required to purchase all renewable energy electricity without any relevant administrative system. The method has established an administrative system to monitor power grid enterprises' purchasing of renewable energy electricity. The method provides for regulatory commission's supervision and management duties, measures and legal responsibilities regarding power grid enterprises' purchasing of renewable energy electricity.

*3.2.8. 11th 5-year Renewable Energy Development Plan (implemented in March 2008)*

NDRC announced the *11th 5-year Renewable Energy Development Plan* in March 2008, specifying renewable energy development goals and priority areas for promotion between 2006 and 2010. The goal of wind power installed capacity by 2010 is doubled, up to 10 GW [7], compared with *the Medium and Long-term Renewable Energy Development Plan*.

*3.3. The effect of support policies*

The above-mentioned laws and regulations can effectively support wind power development and substantially cultivate wind power market in its infancy.

*3.3.1. Cost reduction*

The success of the *Wind Power Concession Program* is evidenced by the great reduction in-grid price for wind power (see Fig. 6). Since the concession was enacted, and the key issues about grid connection, tariff and cost distribution were solved, the enthusiastic about investment in wind power has soared. Under the concession program, the investors and developers of wind power projects are selected through bidding. The bidder who offers the lowest price per kWh of wind electricity in the wind farm usually wins the bid. In the first and second of concession projects, the promise of the former National Planning Commission (the predecessor of NDRC) declared that the bidders proposing the lowest price would win the bids. Since the third round, non-price criteria has been taken into consideration, however, in almost all cases the company with the lowest bidding price won the bid. This suggests that despite the fact that other factors were considered; the bidding price was still the determining factor [5,24,28].

The lowest bidding win the bid has become the unwritten rule. With the game rule, price competition has become fierce. In the bidding, some bidders comprised by the state-owned companies consider the future return over the current return on their current

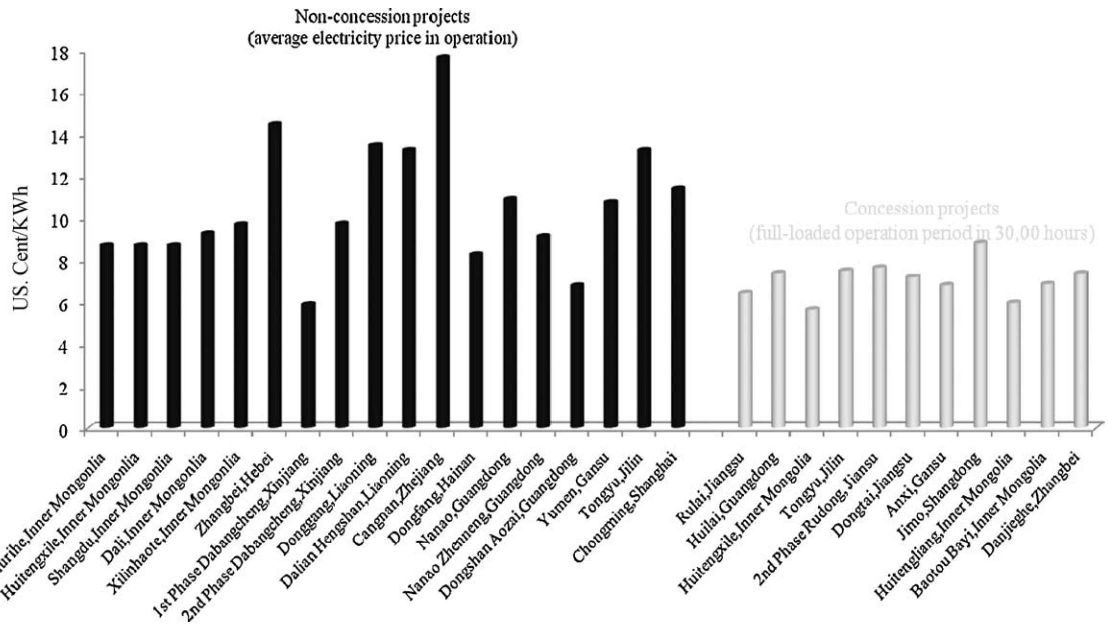



**Fig. 6.** Average electricity price for current wind power projects at the end of 2006 [24].

project for two reasons. First, most of them belong to large national and local energy groups with some kind of monopoly and strong financial backing supported by profitable coal-fired power, hydropower or nuclear power stations. They are therefore able to shoulder a small profit or even a loss from several hundreds of MW of wind power projects. In other words, the state-owned companies can afford to lose money at present, so long as they can control the resources and make profits in 5 or even 10 years. Meanwhile, investing in wind power will win their company a good image for developing clean energy. Second, it may have something to do with the bidding quota policy for renewable energy under discussion. In order to increase investment in renewable energy, the central government has been considering setting a minimum percentage share of renewable energy with the generation output of large power companies. This has made the companies willing to bid for wind power projects with low prices in order to achieve their renewable energy quota [24].

In addition, to decrease the cost of wind power, wind power is a priority "National Clean Development Mechanism Project," i.e., wind farm developers can sell Certified Emission Reduction Certificates (CERs) to developed countries under the terms of the Kyoto Protocol. Renewable energy account for 70% of approved CDM projects in China, on which wind power ranks the first place [31]. Meanwhile, in order to reduce the bidding price, some of the bidders have established joint ventures with companies registered abroad, a method by which they can avoid Value-Added Tax (VAT) and reduce income tax [24].

#### *3.3.2. Localization manufacture*

As mentioned earlier, another criterion in the concession project is the share of domestic components utilized in the wind farm. The bidder who offers the highest share of local content usually wins the bid (see Fig. 7).

To drive wind manufacturing localization, the government waves import customs tariff on the equipment and accessories. The Chinese government adjusted the import custom tariff of wind turbine generator sets to 8% and that of its components to 3% in 2004. The import duty of wind power equipment and accessories can be waived if it is for the wind farm developer's own use. As a result, it can expand the rate of development and improve the manufacturing capacity of domestically made parts. Wind power equipment manufacturers also now enjoy a 50% discount on VAT payable in China. In April 2008, the Chinese Ministry of Finance issued a new regulation on tax refunds for importing large wind turbines (2.5 MW and above) and key components. In this new regulation, the tax revenue for the key components and raw materials for large turbines (2.5 MW and above) will be used for technology innovation and capacity building. The tax rebate is not returned directly to the company, but to the state, which will establish special programs to channel the money back into the wind industry. In August 2008, the Ministry of Finance issued another incentive policy on funding support for the commercialization of wind power generation equipment. According to this regulation, for all the domestic brands (with over 51% Chinese investment) the first 50 wind turbines over 1 MW will be rewarded with 600 Yuan (US$ 88)/kW from the government. The regulation further requires that the rewarded turbines must use domestic manufactured components and share the awards proportionate with component manufacturers [32]. The new policies in 2008 are a strong indicator that the Chinese wind turbine industry is maturing rapidly; as recently as late 2007 Chinese wind power equipment was incapable of producing megawatt-class wind turbines. The new policies will give added impetus to the domestic production of increasingly large wind turbines. China was the fourth largest producer of wind power in the world, after the US, Germany, and Spain in 2007. At present, Chinese enterprises will not only meet the domestic demand, but also begin to supply the international market, especially the parts [32].

#### *3.3.3. Encouraging companies to develop wind power*

The concession program has broken the monopoly over wind power by the former Ministry of Power, helped to draw in investors from both home and abroad, and encouraged competition [24]. The concession agreement and long-term power purchase agreement protect the interests of wind power investors, encouraging large companies to invest in the Chinese wind power sector. In any typical wind power concession, the power grid company signs a long-term power purchase agreement with the wind power project investor and agrees to purchase electricity generated by the project. The bidding competition determines in-grid tariff and the agreement clearly prescribes the quantity of in-grid wind power to be purchased. The duration of the agreement covers the

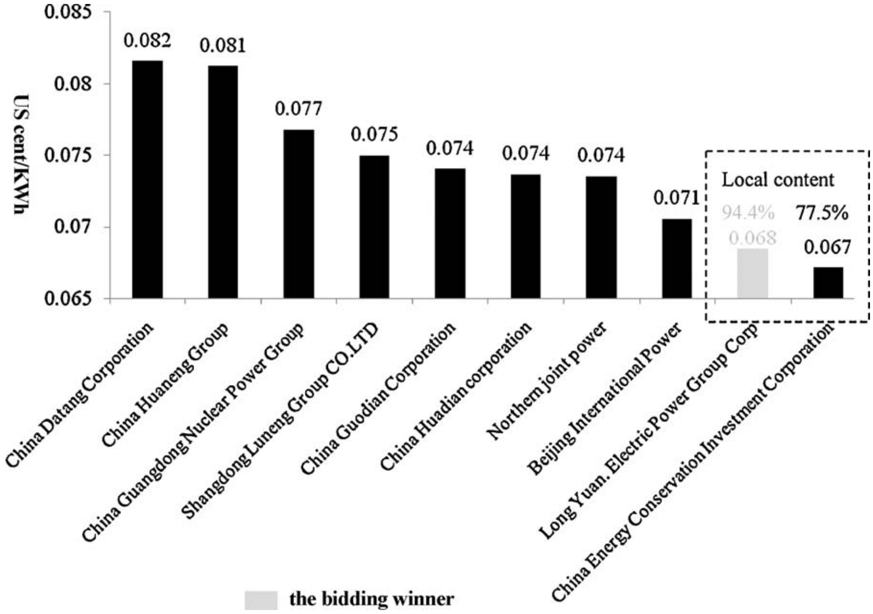



**Fig. 7.** Forth round of wind power concession project at Bayin, Inner Mongolia [5].

total operation period of the wind project. Therefore, the investor minimizes risk in recovering investment costs. The concession agreement between the government and project investor guarantees the power purchase agreement. Under this policy, market risk is reduced significantly, which in turn reduces the risk premium of the internal rate of return for wind power projects.

In addition, the scarcity of wind power resources also lures the investor to bidding. The richest wind farm bases in China are selected for concession bidding in order to conduct the *Wind Power Concession Program* smoothly. For example, six wind farm bases (Hami in Xinjiang Province, Jiuquan in Gansu Province, the Eastern coastal area around Jiangsu Province, Inner Mongolia Province, Zhangbei in Hebei Province, and Baicheng in Jilin Province) will be developed each with a 10 GW-level installed capacity. The planning of 10.65-GW wind power base in Jiuquan of Northwest China's Gansu Province has been completed and construction has started. Xinjiang plans to build a wind power generation base in the Hami area with a capacity of 20 GW. North China's Inner Mongolia aims to form a 20 and 30-GW wind power base in its Western and Eastern part, respectively. Plus, Hebei has proposed to set up a 10-GW wind power base in its coastal and Northern area, and Jiangsu plans to build a 10-GW wind power base including seven GW of capacity in the offshore area [33]. The region with rich in wind power resource is not unlimited in China. Indeed, wind power resource also has the characteristic of scarcity, which lure the investors to bidding.

As a result, the wind industry has experienced a rapid growth in late years (see Fig. 5). The initial target set by *The Medium and Long-term Renewable Energy Development Plan* [26] released on September 2007 was 5 GW by 2010, but the cumulative wind installation exceed 5 GW (6.04 GW) in 2007 [5]. Then the target was up to 10 GW by 2010 [7]. Still the total of wind power installed capacity reached 12.15 GW in 2008. Installed capacity grew by over 105% in 2006 [24], 133% in 2007 [5], 101% in 2008 [8], respectively. The total installed capacity of wind power increased from 2.6 GW in 2006 to 12.15 GW in 2008 [5,8,24] (see Fig. 5). There are four provinces with installed capacity of more than 1 GW, namely Inner Mongolia, Liaoning, Hebei and Jilin in 2008 [8].

In 2009, to cope with the impact of financial crisis, the Chinese government has been regarded the development of wind energy as one of the key economic growth points. According to the current pace of development, China's total installed capacity in 2010 will be the second-largest in the world, realizing the original plan of achieving the goal of 30 GW in 2020 a decade ahead of schedule. China has more than tripled its target for wind power capacity to 100 GW by 2020, likely making it the world's fastest growing market for wind energy technology [34].

### *3.4. The barriers of future develop of wind power*

China is success in wind power installed capacity, however, success in wind-generated electricity has yet achieved. Indeed, a key unanswered question is how to make wind-generated electricity growth as similar as the wind power installed capacity. Two curial barriers are needed to solve for increasing wind-generated electricity.

#### *3.4.1. Backward grid system*

The ability of China's grid system to incorporate wind-generated electricity has become the main challenge faced by China's wind power industry. Among wind farms currently in operation, a great number have only limited access to the grid. According to the *Wind Power Concession Program*, *Renewable Energy Law* and relative laws and regulations, renewable energy should be given priority access to the grid, yet the rule is not being followed due to the physical constraints of grid capacity [5,24,32].

Wind power is often an "intermittent" source whose output level depends on the resources and cannot be entirely controlled. This is an inherent consequence of the application of wind power but not attributable to an individual turbine. With the expansion of wind power and the increase of wind power ratio in a local grid, such unfavorable impact will likely become the technical bottleneck for wind power integration. Wind power decreases accuracy of load forecast and therefore affects power grid dispatching and operation. Moreover, wind power impacts frequency control of power grid, voltage regulation, power supply quality, fault level and stability of power grid [35]. In addition, as mentioned earlier, most of the six wind farm bases are located in Northwest China, while the demand is located in Southeast China. It needs to long-distance and inter-regional transmission from the power supply to electricity consumption. Hence, China's wind power needs updated grid system to support its development.




**Fig. 8.** China's seven-grid system [36].

However, construction and development of China's power grid are sluggish, the grid system is backward and the inter-grid electricity exchange capacity is insufficient. From 2002 to 2007, investment in generation capacity increased from 74.7 billion Yuan (US$ 9.0 billion) to 322.6 billion Yuan (US$ 42.2 billion) at an average annual rate of 28%. At the same time, investment in the grid system increased at a year-on-year rate of only 9%, from 157.8 billion Yuan (US$ 19 billion) to 245.1 billion Yuan (US$ 32.3 billion) [36]. China has not set up a unified power grid network across the nation. Currently, there seven independently operated grids in China (see Fig. 8). China will set up a unified power grid network across the nation by the year 2020 [37].

In addition, grid connection for wind energy requires additional services and therefore increases the operational cost and risks for grid companies, which are state-owned monopolies in China. Without market competition and proper incentives, grid operators have little motivation to expand service to match the rapid development of wind energy. For example, the spokesman of China's grid company said that electricity of wind power should set 8–10% of China's total electricity demand [5]. However, Spain's wind farms provided a record 43% of demand for electricity in November 2008 [38].

In the future, the smart grid would be an ideal solution for grid system to incorporate wind-generated electricity [39]. Unfortunately, China is more favor to build ultra-high-voltage (UHV) power transmission and transformation technology than smart grid. In January 2009, State Grid Corp of China, the country's leading grid operator, said it planned to invest 100 billion Yuan (US$ 14.6 billion) into building ultra-high-voltage power transmission lines over the next 3–4 years [40]. On the contrary, there is few news or report about investment smart grid in China until now, summer 2009.

*3.4.2. Renewable portfolio standard*

A renewable electricity promotion system based on concession approach on international level is an out-dated model due to the negative experiences of the UK. It has brought many problems, especially the issue of low contract implementation rate and its negative impact on the industry development in UK. Indeed, UK switched to a promotion system based on renewable energy quotas in combination with tradable Green Certificates [24]. A renewable portfolio standard mechanism generally places an obligation on electricity supply companies to produce a specified fraction of their electricity from renewable energy sources [41].

Indeed, some bidders do not want to construct the wind power farm, but care of "occupying" the wind natural resources in some wind power concession projects. As mentioned earlier, the NDRC offers the regions with rich in wind power to bidding in order to conduct the concession program smoothly. Wind resource is also a nature resource, indicating that wind power resource has the characteristic of scarcity. The region where is rich in wind power is not unlimited in China. It is awful that some bidders care of more occupying the limited "wind natural resources" than construction wind farm. Fortunately, Chinese policy maker has noticed this problem. On 5 January 2006, the NDRC issued "*NDRC [2006] No. 13 document-related Regulations regarding Renewable Energy Power Generation*". It stipulates that power enterprises should actively invest in renewable energy power generation projects and accept the obligation of a renewable energy power generation quota. The quota allocation will be stipulated in other documents. However, the renewable portfolio standard has yet enacted until now, summer 2009. It is time that renewable portfolio standard is adopted in order to wind power further development, as well as to avoid the unbalance development between wind power installed capacity and wind-generated electricity.

## 4. Lessons for PV generation

China is rich in solar energy [25] and has a huge production capacity of solar cell, however, the installed capacity of photovoltaic power generation is very small [42]. As the development of wind power installed capacity is considered a success story, can the drivers of promotion wind power transferable to photovoltaic power?

*4.1. General information regarding China's PV*

China lies in the Northeastern part of East Asia between 4° and 53° North latitude and 73° to 135° East longitude covering an area of 9.6 million km$^2$. More than two-third of the country receives an annual radiation of more than 5000 MJ/m$^2$ and more than 2000 h of sunshine [25] (see Fig. 9).

Since 2004, China's solar cell has experienced rapidly growth, inspirited the booming of German PV market. The total output of

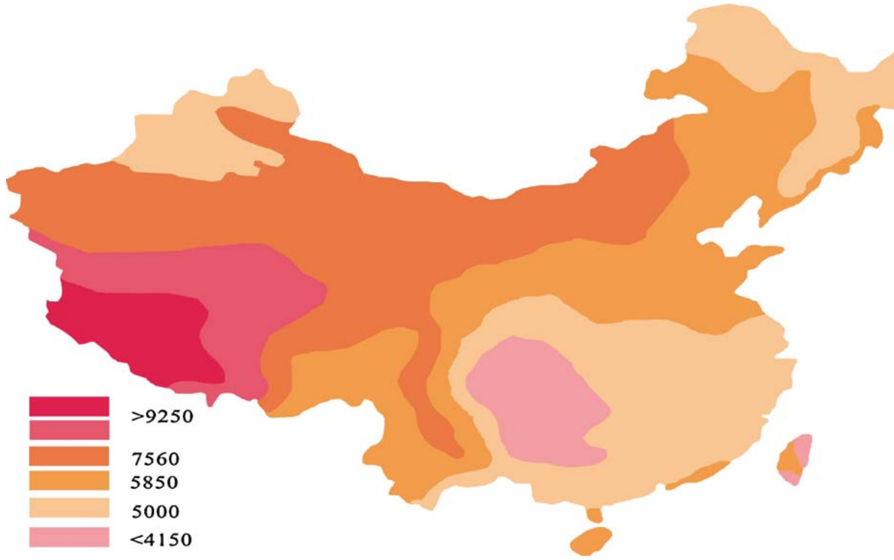



**Fig. 9.** The statistics of solar energy density in 2008 (MJ/m$^2$ per year) [25].

China's solar cell in 2007 was 1088 MW, ranking it first in the world [11] (see Fig. 10). Although China is a top manufacturer of solar panels, the high cost of the most efficient technologies hinders their deployment. By the end of 2007, the total installed capacity of photovoltaic power generation was about 105 MW, and the new PV capacity 25 MW (see Fig. 11). Namely, more than 90% of China's solar cell exports to overseas [42].

### *4.2. Recommendation*

The high cost of PV power generation is the biggest barrier. In 2007, the average on-grid electricity price of PV power plants is 4 Yuan (US Cent 58.9)/kWh [43], compared to the average on-grid electricity price of wind power 0.617 Yuan (US Cent 9.1)/kWh, nuclear power 0.436 Yuan (US Cent 6.4)/kWh, coal-fired plant 0.346 Yuan (US Cent 5.0)/kWh, and hydropower 0.244 Yuan (US Cent 3.6)/kWh [44] (see Fig. 12). It is must to reduce the cost of PV power generation substantially by technological advancement or by energy policy support in order to enable the solar power generation to advance on a large scale. The best practices of wind power show that the good energy policies can effective decrease the cost of power generation. China needs the substantial program as well as the policy to build environments that encourage the solar energy, so as to advance its rich solar energy resource and to use it's the great production capacity.

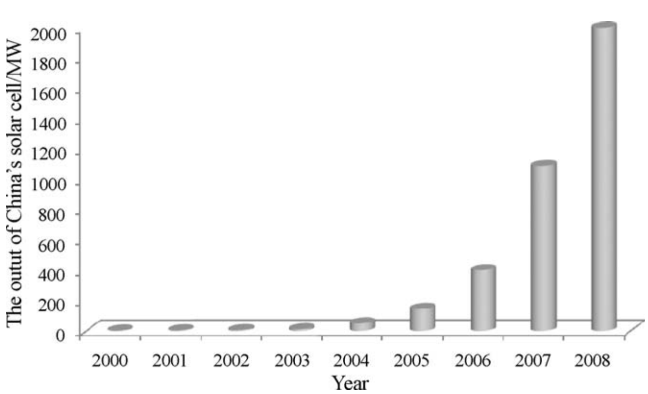



**Fig. 10.** The output of China's solar cell in the past 9 years (source: http://www.solar-pv.cn/ and news).

As mentioned earlier, the landmark *Renewable Energy Law* and a couple of additional laws and regulations were neither custom-made nor focus on the wind power, while one special characteristic of wind power is the "*Wind Power Concession Program*" [24,28]. Therefore, solar energy concession program is proposed as a good solution to reduce the cost of PV and thus to advance the PV installed capacity.

Indeed, the Chinese government has, in 2009, initiated 10 MW concession demonstration project in Dunhuang, Gansu Province. The Dunhuang project has reached a historically turn point to most Chinese PV makers. There were 18 bidders for the 10 MW solar photovoltaic projects. And then, five of those submitted were

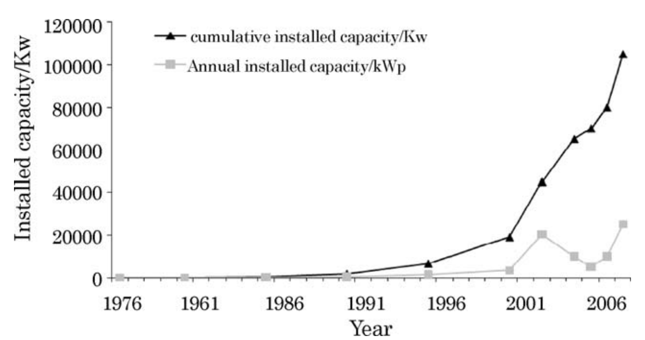



**Fig. 11.** The accumulative total of solar energy generating system in the past 30 years [42].

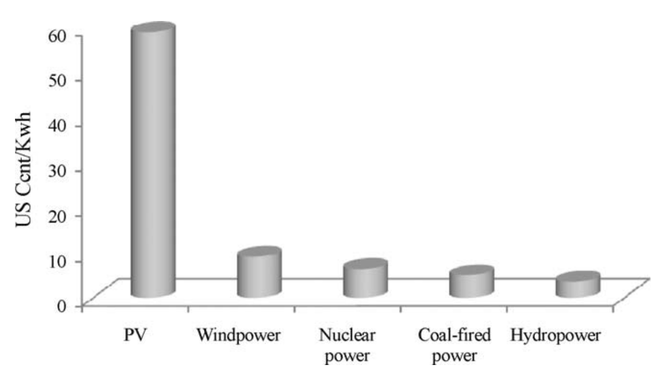



**Fig. 12.** Comparison average on-grid electricity price of PV with of other source-driven electricity [43,44].

disqualified for not meeting technical requirements. The remaining 13 bids provided some fierce competition, as reflected in the surprisingly low range of tariff rates proposed by the bidders. The prices disclosed were way below the perceived 2 Yuan (US$ 0.29)/kWh as predicted. The highest price was offered by China Guangdong Nuclear Wind Power, at 1.92 Yuan (US$ 0.28)/kWh, and the lowest by SDIC Huajing Power, and its bidding partner, NYSE-listed Yingli Green Energy, at 0.69 Yuan (US$ 0.10)/kWh, followed by the second lowest at 1.09 Yuan (US$ 0.16)/kWh from China Guangdong Nuclear Energy. The prices from others were within the range of 1.1 Yuan (US$ 0.16)/kWh to 1.6 (US$ 0.23)/kWh. Prices from consortium bidders were generally lower than others. Though the winning bid has yet to be officially announced, it is expected that the bidders with the lowest proposed tariff rate to win the concession. Indeed, employees from SDIC Huajing and Yingli Green Energy, are already claiming to be the winners [45]. They are fast approaching the retail rate of wind generation electricity of nearly 0.6 Yuan (US$ 0.09)/kWh. The extraordinarily low prices disclosed clearly indicate that the concession program can substantially decrease the cost of PV, just like it did for China's wind power.

Some suspect that it seems more likely that these state-owned enterprises are willing take a hair-cut on profitability just for the prestige of winning in the first ever solar concession and to start securing market share in this new industry. Also, others criticize that such low price is harmful the future healthy development of China's PV [45,46]. However, no one can deny the fact that the solar power concession has effectively decreased the cost of PV power generation. In 2007, PV generation electricity was 4 Yuan (US Cent 58.9)/kWh, and then in September 2008, Suntech Power Co., Ltd. China, Chinese biggest solar cell producers declared that it can reduce the PV power price to 1 Yuan (US$ 0.15)/kWh by 2012. However, in March 2009, the PV concession demonstration project has propelled the PV generation to reduce to 0.69 Yuan (US Cent 0.1)/kWh. It is optimism that PV installed capacity will be rapid growth with the solar energy concession program. It is also noted rapid growth of PV-generated electricity will not be achieved, if the grid system was not improved or the quota system was not adopted.

## 5. Conclusion

Curbing the carbon emission and ensuring energy supply are two of the most challenges for China to achieve its industrialization and modernization. Renewable energy is a good solution, for renewable energy is neither almost emission greenhouse gases nor exhausted. Albeit China shows a strong need to widely increase its renewable energy use, there are still some constraints to be taken into account. To overcome such barriers and increase the competition of renewable energy with traditional fossil energy, a series of substantial and effective renewable energy policies are needed. The rapid growth of China's wind power installed capacity is a good example. In addition the landmark *Renewable Energy Law* and a couple of additional laws and regulation, the most characteristic of the driving forces of the Chinese success in the promotion and development of wind power is "*Wind Power Concession Program*". The described concession program might easily be transferable to the China's PV. For further develop China's wind power and solar energy, updated the grid system and the Renewable Portfolio Standard are necessary.

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